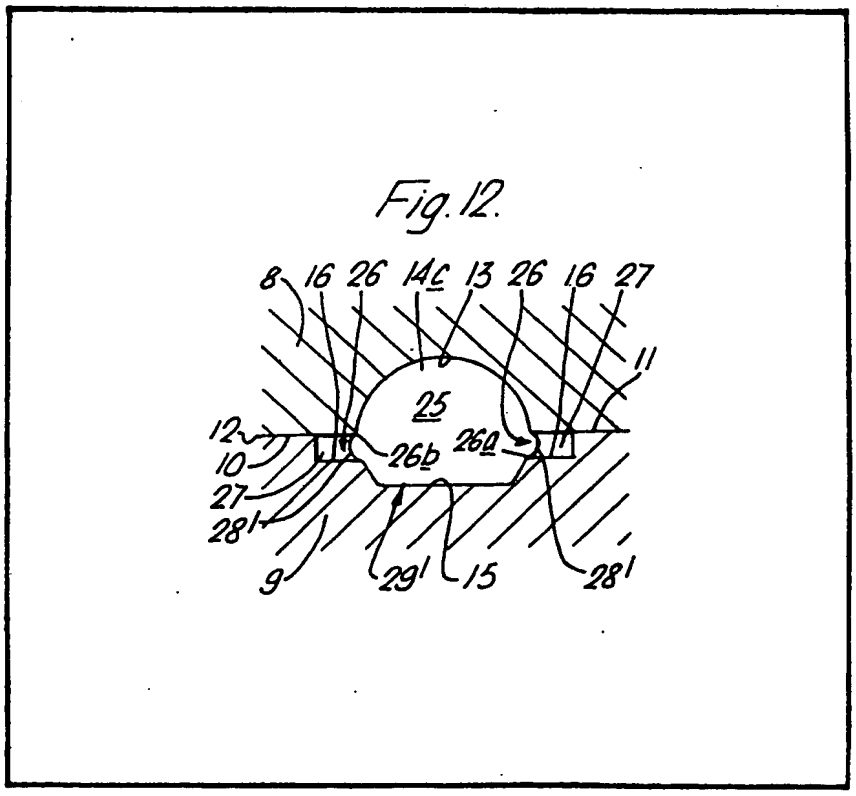
(12) UK Patent Application (19) GB (11) 2 108 026 A

(21) Application No 8132679
(22) Date of filing 29 Oct 1981
(43) Application published
11 May 1983
(51) INT CL³
B21J 5/02
(52) Domestic classification
B3H 2U
B3A 73
(56) Documents cited
None
(58) Field of search
B3H
(71) Applicant
Cam Gears Limited,
(Great Britain),
45 Wilbury Way,
Hitchin,
Hertfordshire,
SG4 0TU
(72) Inventor
Peter Rowland Rogers
(74) Agent and/or address for service
Urquhart-Dykes and Lord,
47 Marylebone Lane,
London,
W1M 6DL

(54) Manufacturing a rack member

(57) A rack member 14c is manufactured by pressing a longitudinally extending workpiece of circular or other section between die parts 8 and 9. Die part 8 has a longitudinal recess 13 within which the workpiece is partly received to oppose an array of rack teeth 15 in a wall of the die part 9. The teeth 15 are complementary to those which are to be pressed in the workpiece. Opening into the face 11 of the die part 9 along the parting plane 12 of the die parts is a pair of longitudinally extending and opposed rebates 16 which form relief cavities 27 opening from the die cavity 25 through relief outlets 26. During pressing of the workpiece surplus material from the workpiece is displaced uninhibited from the die cavity 25 into the relief cavities 27 to relieve stress in the workpiece and alleviate the formation of malformed teeth on the pressing. The displaced material can be removed at an intermediate stage of pressing to alleviate the requirement of a high closing pressure on the die parts.



GB 2 108 026 A

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

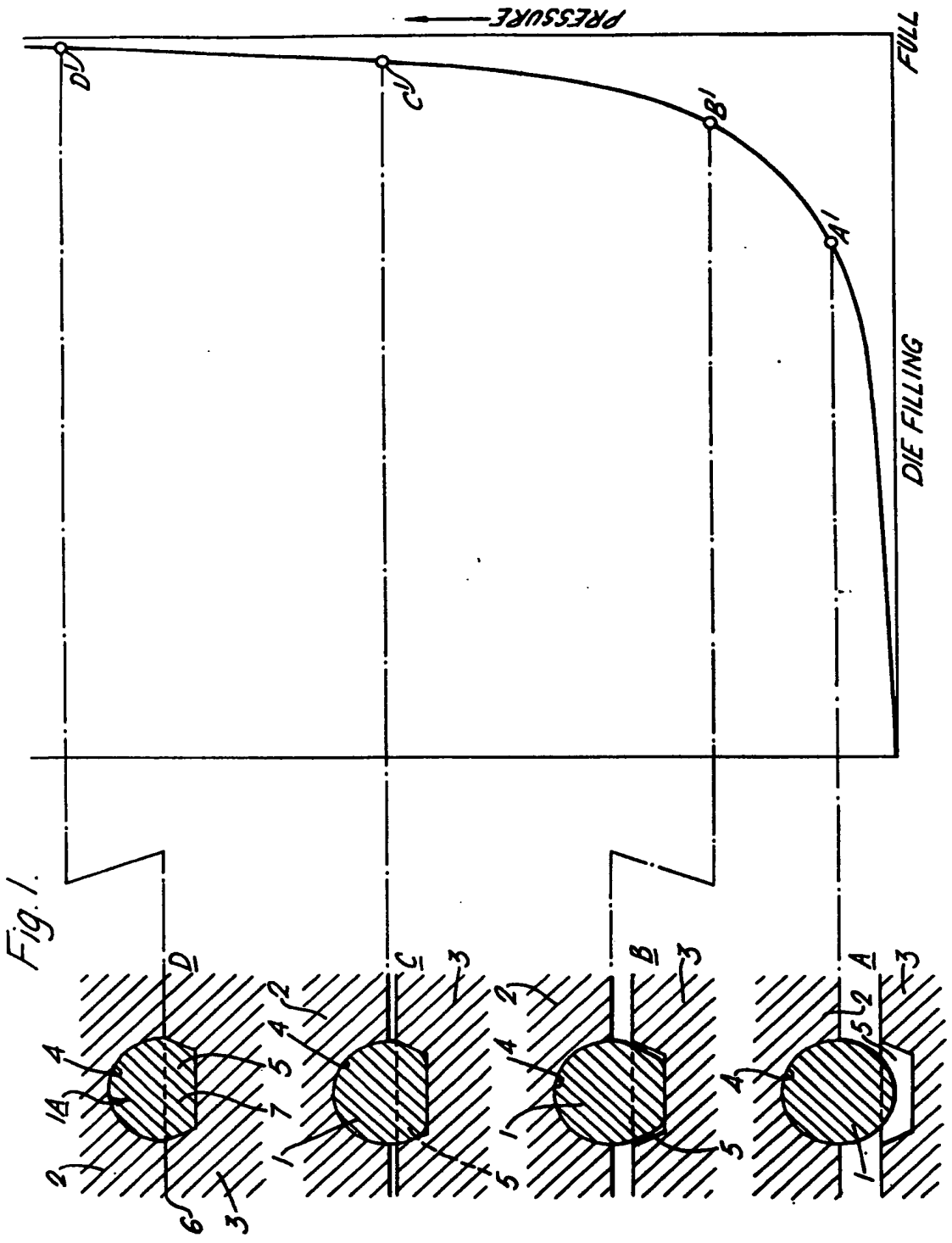


Fig. 1.

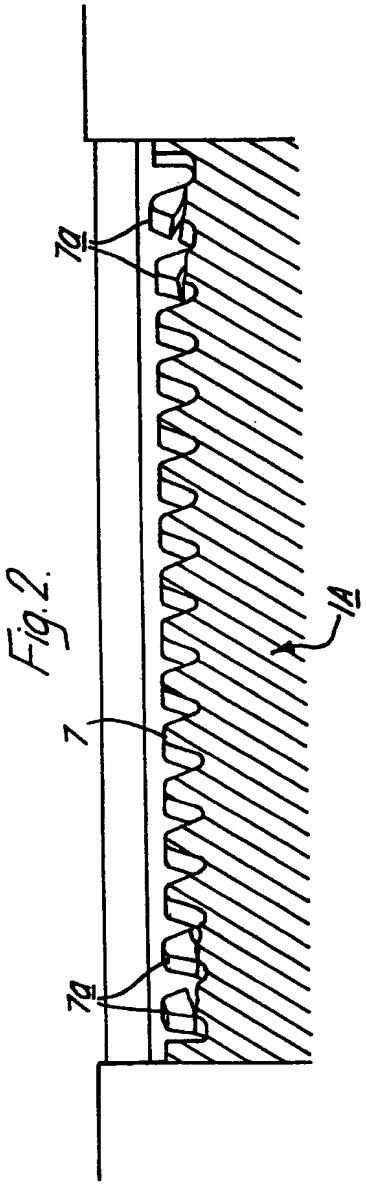


Fig.2.

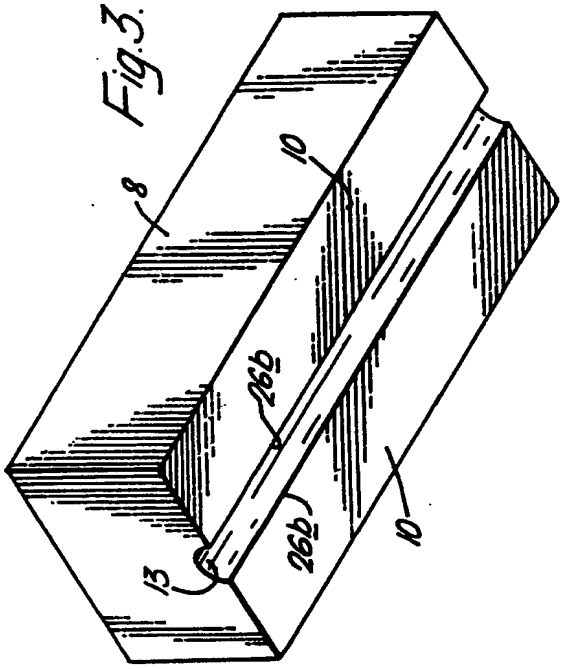


Fig.3.

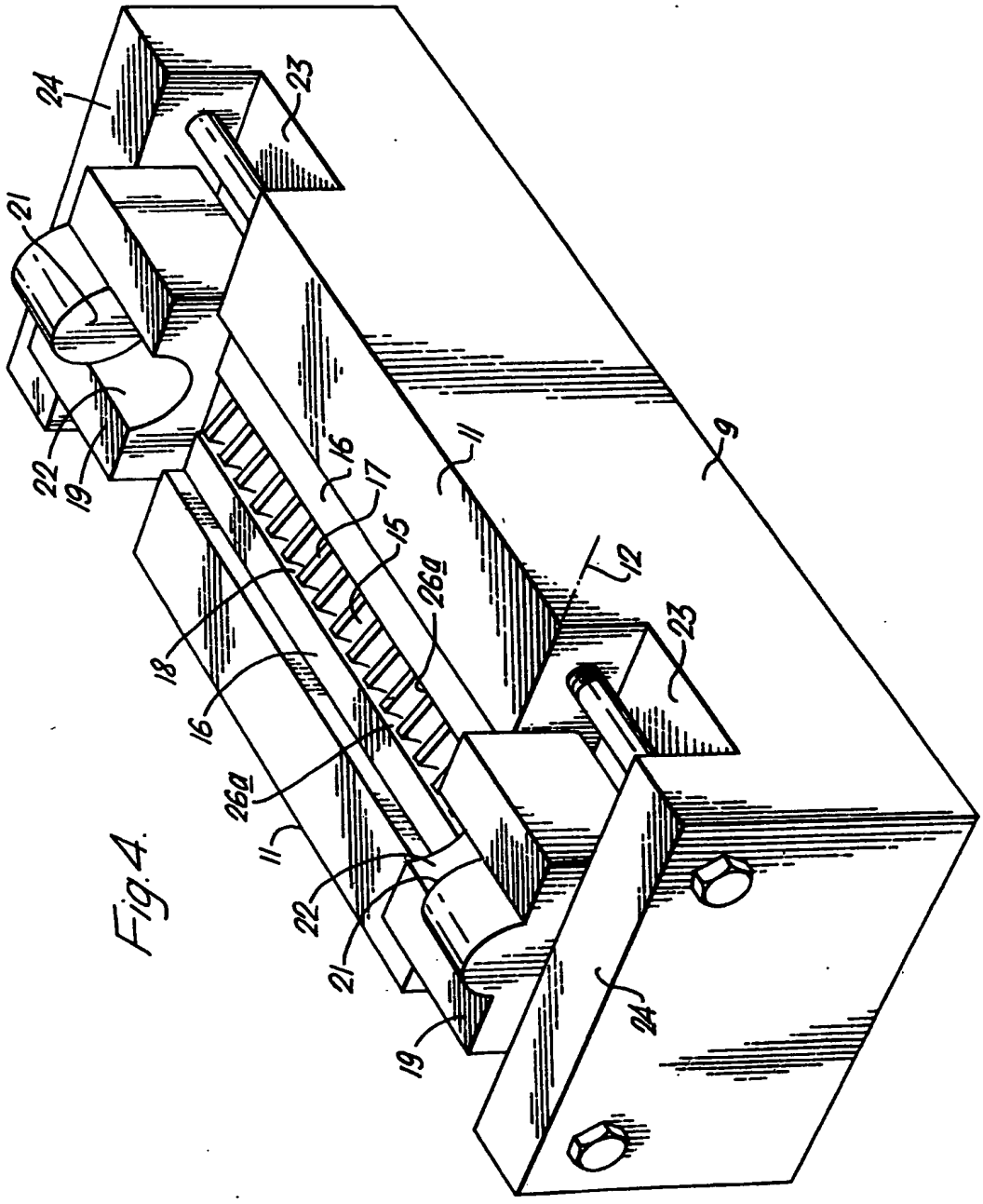


Fig. 4.

Fig.6.

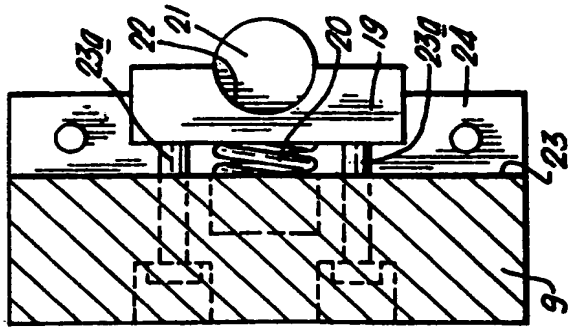
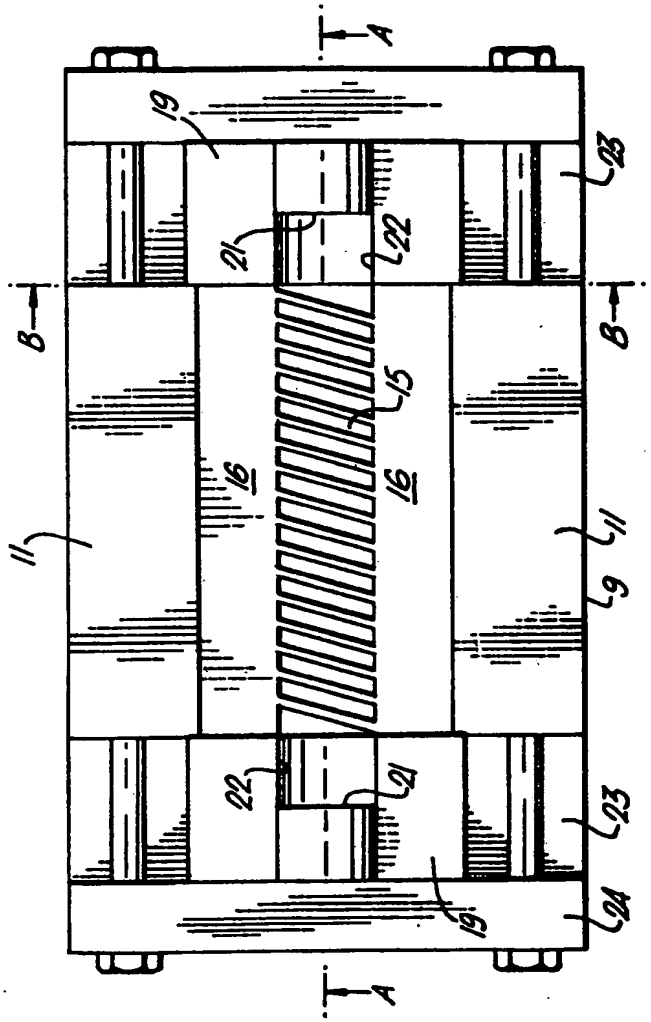

23a
22
21
20
19
23a
24
23
9

Fig.5.


A
19
23
21
22
B
B
15
16
16
11
11
9
22
21
23
19
24
A

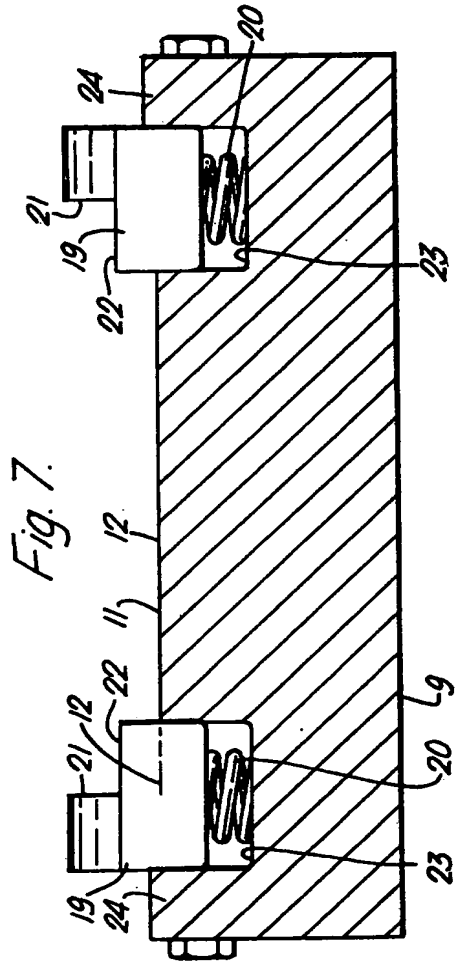


Fig. 7.

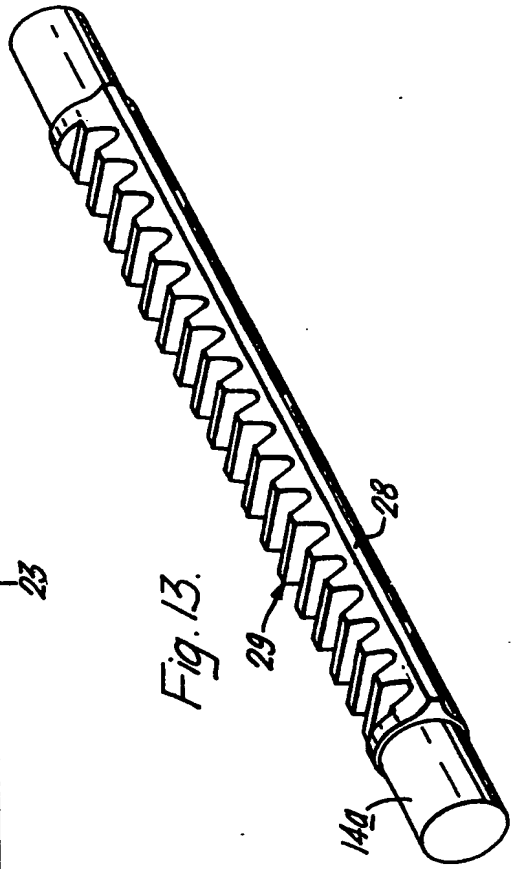


Fig. 13.

Fig. 8.

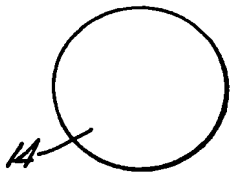


Fig. 9.

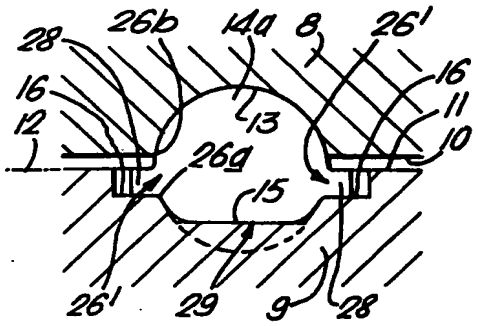


Fig. 10.

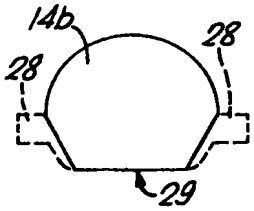


Fig. 11.

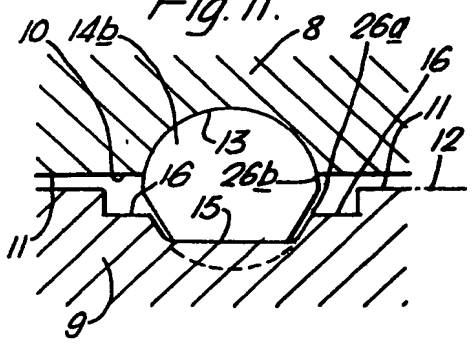
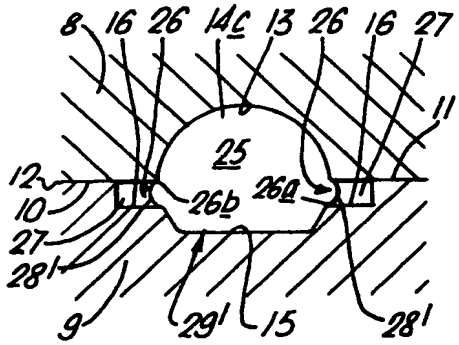


Fig. 12.



SPECIFICATION

An apparatus for and method of manufacturing a rack member, and a rack member manufactured by the aforementioned method

Technical field

The invention relates to the manufacture of a rack member in the form of a longitudinally extending component having a longitudinally extending array of rack teeth in its surface. Such a rack member is usually intended for meshing engagement with a pinion to provide a gear where rotation of the pinion effects in longitudinal displacement of the rack member; a gear of this kind is well known, for example, in vehicle steering systems.

Background art

Conventional rack and pinion gears provide a constant transmission ratio between rotation of the pinion and displacement of the rack member. For such a constant ratio the rack teeth and also those of the pinion are of constant uniform pitch and uniform shape, possibly with the rack teeth inclined relative to the longitudinal extent of the rack member at a constant angle where those teeth are to engage with a helically toothed pinion. Rack teeth of such constant form are conventionally shaped on a workpiece by use of broaching techniques. Variable ratio rack and pinion gears have long been known (for example, from U.K. Patent 1,356,172) where the pitch, profile and inclination of the teeth varies along the length of the rack so that when those teeth are drivingly engaged by a helically toothed pinion there is a variation in the transmission ratio. Because of their varying form the shaping of the teeth by broaching is impractical and there is a problem of economically manufacturing the teeth, particularly on a commercial scale. Variable ratio rack and pinion gears are finding increasing favour in the motor industry for use in steering systems and the problem of achieving a viable means of manufacturing the rack member is considerable. In an attempt to alleviate this problem it has been proposed to form the teeth by hot or cold coin pressing. A particular advantage to the gained by coin pressing is that once the teeth have been formed their further machining is unnecessary. However, coin pressing of a steel workpiece acceptable for use as a steering gear component requires tremendous pressure on the die parts. The provision of die pressing machines with the high pressures required for such coin pressing result in high cost for the manufactured component. Furthermore, by use of conventional coin pressing techniques on a plain part from which the rack member is to be formed it frequently occurs that several of the teeth pressed in the rack (particularly those towards each end of the rack) are malformed and possibly fractured. It is believed that this failure of the pressing technique is due to the problem of elongation in, and ensuring appropriate displacement of, the workpiece material during pressing bearing in mind that the density of the teeth per unit length of the rack is not uniform. In an attempt to alleviate this latter problem it has also been proposed to partially preform the rack teeth on a workpiece by machining prior to that workpiece being cold pressed to finish the tooth formation. Such partial preforming of the rack teeth is a lengthy and expensive procedure not favoured for manufacture of rack members on a commercial scale.

It is an object of the present invention to provide an apparatus and method by which a rack member can be formed by pressing in a manner which alleviates the disadvantages discussed above and which is particularly suitable to the formation of teeth in either a uniform, constant ratio rack or a variable ratio rack where the teeth may be of varying pitch, profile and angular relationship with respect to the longitudinal extent of the rack.

Statement of invention and advantages

According to the present invention there is provided apparatus for manufacturing a rack member comprising a press with openable and closable die parts for receiving a longitudinally extending workpiece on which a longitudinally extending array of rack teeth is to be formed, said die parts when closed co-operating to provide a die cavity having a toothed wall part complementary in shape to the array of rack teeth which are to be pressed on the workpiece during closing of the die and wherein said die cavity has at least one laterally directed relief outlet communicating therewith in a parting plane of the die parts and clear of the toothed wall part through which excess material from said workpiece can be displaced laterally during the pressing of the teeth.

Further according to the present invention there is provided a method of manufacturing from a longitudinally extending workpiece a rack member having a longitudinally extending array of rack teeth which comprises locating the workpiece between opened die parts, said die parts being closable to co-operate and provide a die cavity having a toothed wall part complementary in shape to the array of rack teeth; closing the die parts under pressure to press the workpiece to a required shape of toothed profile and maintaining, during said closing and when closed, at least one laterally directed relief outlet which communicates with the die cavity in a parting plane of the die parts clear of the toothed wall part and through which excess material from the workpiece is displaced laterally during the pressing of the teeth.

Still further according to the present invention there is provided a rack member when manufactured by the method in accordance with the immediately preceding paragraph.

In conventional coin pressing techniques, the die parts when closed define a die cavity which corresponds to the shape and size of the article to be pressed and the volume of the workpiece is

selected, within practical tolerances, so that under pressure on the dies it is displaced or flows to fill the die cavity. This conventional technique is that when has previously been proposed for pressing rack members and which resulted in the previously discussed problems. However, by the present invention the die parts when closed, and also during their closing, define one or more laterally directed relief outlets through which excess material from the workpiece is displaced. It is believed that the provision of such a relief outlet permits the material of the workpiece to be displaced and flow strain free to form the required tooth profile within the die cavity while the excess material is laterally displaced uninhibited through the relief outlet or outlets.

To ensure accurate formation of the pressed teeth it is preferred that the workpiece is restrained from longitudinal extension during pressing of the teeth. This restraint is conveniently provided by the use of longitudinally opposed end stops between which the workpiece is longitudinally received when in the die parts. Such an arrangement of end stops facilitates the use of die parts which are relatively short longitudinally to correspond with the desired length of rack while the workpiece located between the opposed end stops can be a relatively long bar member which extends from longitudinally opposite side of the die parts.

It is a further preference that the or each laterally directed relief outlet extends longitudinally of the die parts to be substantially co-extensive with the rack teeth which are to be pressed while being so positioned that excess material which is displaced through the relief outlet or outlets does not detract from the required finished profile of the teeth when pressed. By use of a longitudinally extending relief outlet as aforementioned such excess material as is displaced therethrough may provide a longitudinally extending flange or rib on the workpiece following pressing which flange or rib may be surplus to the desired finished shape which is required of the rack member. A preferred position for the laterally directed relief outlet is immediately below (with respect to the upstanding rack teeth) where the roots of the rack teeth will be formed in the workpiece (that is adjacent to the toothed wall part of the die parts).

The present invention may be applied to the pressing of a workpiece in which the teeth are partly preformed prior to the pressing operation; however, this is not preferred due to the expense of subjecting the workpiece to the preforming operation. As a consequence it is preferred that the workpiece is a plain bar or thick walled tube where it has been found, due to the provision of the relief outlet, that the cross-sectional shape for such a plain workpiece is not particularly critical in determining the efficiency with which the workpiece is pressed into its desired toothed shape.

The or a relief outlet may comprise a relief cavity which is formed between the die parts when closed and which communicates with the die cavity to receive excess material from the workpiece during pressing. To ensure appropriate flow of the workpiece material within the die cavity during pressing it should be ensured that the volume of the relief cavity is greater than that which is likely to be filled by excess material which is displaced into it otherwise such a relief cavity would then, in effect, merely become part of the die cavity.

The relief outlet is conveniently formed by rebating one or more of the die parts in the parting plane or planes with adjacent die part or parts. Usually the die will consist of two opposed die parts one of which has the toothed wall part complementary to the shape of the array of rack teeth which are to be pressed and one of these die parts may be rebated along its parting plane or line with the other as aforementioned to provide the relief outlet or outlets. With such a two part die it is preferred that there are two laterally opposed relief outlets which, with the die parts closed, extend longitudinally of the workpiece substantially parallel with and adjacent to the complementary array of rack teeth provided in the toothed wall part of one of the die parts.

As mentioned above, the excess material which is displaced from the die cavity during pressing of the workpiece is likely to provide a protrusion such as a flange or rib which is surplus to the shape required of the finished rack member. It is preferred therefore that the present invention comprises the steps of partially forming the teeth on the workpiece during partial closing of the die parts; substantially removing from the workpiece the excess material displaced through the relief outlet or outlets and subjecting the workpiece to further pressing to complete the tooth formation by full closure of the die parts. Usually the workpiece with its teeth partially formed will be removed from the die parts to effect removal (for example by milling or grinding) of the excess material displaced through the relief outlet or outlets prior to further pressing of the teeth between the die parts. The initial pressing of the workpiece and the further pressing subsequent to removal of the excess material is conveniently, but not necessarily, effected by the same set of die parts. Following removal of the excess material which is displaced through the relief outlet or outlets and subsequent pressing of the workpiece to complete the formation of the rack teeth it is likely that further excess material will be displaced through the relief outlets but this may be of such a small volume as to be neglected; indeed where the excess material forms a longitudinally extending rib which is co-extensive with the rack such a rib may conveniently serve for the purpose of mounting the rack member in a pinion housing, for example to restrain rotation of the rack member.

Figures in the drawings

One embodiment of the present invention will now be described, by way of example only, with

reference to the accompanying illustrative drawings, in which:—

Figure 1 diagrammatically and graphically shows a prior proposal for coin pressing of a rack member by use of conventional techniques;

Figure 2 is a sectional side elevation of a rack member as may be formed by the conventional technique of Figure 1;

Figures 3 and 4 are perspective views respectively of upper and lower die parts for use in the manufacture of a rack member in accordance with the present invention;

Figure 5 is a plan view of the lower die part of Figure 4;

Figure 6 is a section of the lower die part taken on the line B—B of Figure 5;

Figure 7 is a section of the lower die part taken on the line A—A of Figure 5;

Figures 8 to 12 diagrammatically illustrate the progressive steps of manufacture of a rack member by use of the die parts in Figures 3 and 4, and

Figure 13 is a perspective view of a workpiece showing rack teeth pressed therein by use of the die parts of Figures 3 and 4 and at an intermediate stage (corresponding to Figure 9) in the manufacture of the rack member.

Description with reference to the drawings

The general structure of a rack member for meshing engagement with a pinion is well known as comprising a longitudinally extending component such as a bar or thick walled tube having a longitudinally extending array of rack teeth in its surface. Usually rack members are manufactured from solid cylindrical stock and, for convenience, the present invention will be discussed with this in mind; however, it is to be realised that the stock from which a rack member may be pressed may be of a shape other than circular in lateral section. In a prior proposal the array of rack teeth are formed in a cylindrical bar by pressing the bar between opposed die parts using conventional coin pressing techniques. Such a conventional proposal is shown in Figure 1 where the lefthand side of the Figure shows the progressive stages of pressing with sequential diagrams A to D and the righthand side of the Figure graphically illustrates in the ordinate the progressive increase in pressure on the die parts to effect moulding and in the abscissa the extent to which the die parts are closed and filled by displacement of the workpiece material (the positions on the graph shown at A′ to D′ sequentially correspond to the die closure positions A to D respectively).

In diagram A of Figure 1 the cylindrical workpiece 1 is located between an upper die part 2 and a lower die part 3. The die part 2 has a part cylindrical recess 4 within which the workpiece 1 is partly received to oppose a profiled and recessed wall part 5 in the lower die part 3. The wall part 5 is profiled as an array of rack teeth which are complementary to the rack teeth which are to be pressed in the surface of the workpiece 1. The die parts 2 and 3 are closable so that the opposed recess 4 and wall part 5 define a die cavity which corresponds to the shape desired of the rack member over a longitudinal extent thereof which includes the rack teeth. To facilitate use of the die parts on different lengths of cylindrical stock, the workpiece 1 projects longitudinally from opposite ends of the die parts. Upon initial closing of the die parts 2 and 3 the workpiece 1 engages the toothed wall part 5 to be displaced over the teeth and such displacement progressively increases as the die parts are closed as shown in the sequential diagrams A to D. At the final stage of closure in diagram D the die parts 2 and 3 move into abutment over a parting plane 6 and the workpiece material has been displaced to fill the die cavity to form the rack member 1A.

The rack member 1A formed by the closed die parts in diagram D illustrated in Figure 2 from which it will be seen that the longitudinally extending array of rack teeth 7 have been pressed into the surface of the original cylindrical workpiece 1. From the graph in Figure 1 it will be seen that the pressure required of the die parts to displace the workpiece 1 into the appropriate shape increases exponentially as the die closure progresses sequentially through the steps of diagrams A to D. It will be seen further that although during closure of the die parts from steps B to D very little displacement of the workpiece is required it is necessary, in order to achieve this final displacement of the material, to apply a considerable increase in pressure to the die parts over the points B′ to D′ on the graph. It is believed that the differentials in elongation and stress which are applied to the workpiece by the high die pressures necessary for the final formation of the rack teeth are the prime cause of malformed teeth which frequently occur in the pressed rack by the above described conventional pressing technique. Generally these malformed teeth are located towards opposite ends of the rack and are illustrated, by way of example, as fractured teeth 7*a* in Figure 2. Not only is this conventional pressing technique believed to be unacceptable commercially because of the high incidence of malformed teeth but also the provision of equipment necessary to provide the high pressures required to effect full closure of the die parts adds considerably to production costs. It is an object of the present invention to alleviate these disadvantages of the conventional proposals and an embodiment of how this may be achieved will now be described.

The embodiments of the Applicants rack pressing technique utilises an upper part 8 and a lower die part 9 (see Figures 3 to 7). The die parts 8 and 9 have flat faces 10 and 11 respectively which oppose each other and are intended for face-to-face abutment in a parting plane 12 (see Figure 7) when the die parts are closed. Machined in the face 10 of the upper die part is a longitudinally extending part cylindrical recess 13 within which a substantially

complementary cylindrical workpiece 14 (Figure 8) is to be partly received.

Provided in the lower die part 9 beneath the face 11 but open to the parting plane 12 is a longitudinally extending array of rack teeth 15. The array of teeth 15 is complementary to the array of teeth which is to be pressed into the workpiece 14 and the teeth 15 are located to oppose the recess 13 in the upper die. The teeth 15 may be formed in the die part 9 by, for example, electrolysis techniques or may be pre-machined on an insert appropriately secured within the lower die part. The pitch, profile and annular relationship of the teeth 15 with respect to the longitudinal extent will likely vary along the array for the pressing of a rack member for a variable ratio rack and pinion gear as previously described although such teeth may be of constant form for a constant ratio gear. Machined in the die part 9 to open into the parting plane 12 and on opposite sides of the rack teeth 15 are a pair of longitudinally extending shouldered rebates 16. These rebates 16 are clear of the teeth 15 and have a depth with respect to the face 11 which is slightly less than the crowns 17 of the teeth 15 so that a small clearance 18 is provided between the teeth 15 and the respective rebates 16. In practice the clearance 18 may be in the order of 0.05 cms. The depth of the rebates 16 is not critical and may be in the order of, say, 0.4 cms.

Located at longitudinally opposite end of the rack teeth 15 are a pair of carriages 19 which are mounted by springs 20 on the die part 9 to be displaceable perpendicularly to the parting plane 12. The carriages 19 have part cylindrical seats 22 which are complementarly to and are intended to partly receive opposite ends of the cylindrical workpiece 14 between longitudinally opposed end stops 21 on the carriages. In their unstressed condition the springs 20 locate the carriages 19 with their seats 22 proud of the rack teeth 15 and these carriages are intended to be displaced against their spring loading by closing pressure of the die parts. The stops 21 on the carriages 19 are intended to restrain the workpiece from longitudinal extension during pressing and accordingly the carriages are displaceable in recesses 23 on slide bars 23*a* in the die part 9 so that braced wall parts 24 of that die part prevent the stops 21 from longitudinal displacement away from each other.

With the upper die part 8 matched with the lower die part 9 the end stops 21 are received within the recess 13 and are of a complementary cylindrical profile for this purpose. As the die is closed it will be apparent that the carriages 19 will be displaced downwardly in Figure 4 with their slide bars 23*a* until the faces 10 and 11 abut each other in the parting plane 12. In this latter condition the recess 13 longitudinally opposes the array of teeth 15 and there is formed (see Figure 12) a die cavity 25 which communicates through longitudinally extending and opposed relief outlets 26 with a pair of longitudinally extending relief cavities 27. Each relief cavity 27 is formed, when the die parts 8 and 9 are fully closed, between one or other of the rebates 16 and the longitudinally extending portion of the die face 10 which opposes that rebate. Each such relief cavity 27 opens to the die cavity 25 through its associated relief outlet 26 which is in the form of a longitudinally extending slotted aperture fored by the edge 26*a* of the respective rebate 16 adjacent to the die cavity 25 and the respective longitudinally extending edge 26*b* of the die face 10 adjacent to the recess 13 which substantially overlies it. The die cavity 25 includes the rack teeth 15 and recess 13 and is substantially complementary in shape to that which is desired for the rack member which is to be pressed from the workpiece 14.

To form the rack member the workpiece 14 is located in the seats 22 of the lower die part 9 with the upper die part 8 open. The length of the cylindrical bar 14 is selected to be a close sliding fit between the end stops 21. The opposed die parts are now closed towards each other as shown in Figure 9 to apply pressure to, and cause, the workpiece material to be displaced into the teeth 15 and over the rebates 16 (through the relief outlets shown at 26′ which are progressively forming)—during this and subsequent deformation of the workpiece 14 the latter is restrained from the longitudinal extension by the end stops 21. The material which is displaced through the relief outlets 26′ and into the rebates 16 may be regarded as surplus to requirements but it is the uninhibited flow of this surplus material together with the longitudinal constraint of the workpiece which is believed to relieve stress in the body of the material and ensure that a commercially acceptable product is pressed.

As the die parts move towards a fully closed condition material is increasingly displaced onto the rebates 16 with the result that opposed longitudinally extending flanges or ribs 28 are formed together with an array of partially formed rack teeth 29 as the material is increasingly displaced into the teeth 15. When the die parts have moved towards each other to the extent shown in Figure 9 (which substantially corresponds to the closure position shown in diagram B of Figure 1 for the conventional pressing technique), the die parts are opened and the partially moulded workpiece 29 (see Figure 13) is removed.

At this intermediate stage of forming of the rack member the material which is surplus to requirements, particularly the flanges 28, is machined off as shown in Figure 10. The resulting machined workpiece 14*b* is now relocated in and matched to die parts 8, 9 which are closed as shown in Figure 11 to a position corresponding to that reached in Figure 9.

The final pressing of the workpiece 14*b* to form the rack member 14*c* is now effected by moving the die parts 8, 9 to a fully closed condition so that the die faces 10 and 11 move into abutment with each other on the parting plane 12 as shown in Figure 12. During final closing of the die parts

the material of the workpiece 14*b* is displaced into the teeth 15 to reproduce a toothed profile 29 which accurately complements those teeth 15. In addition material which may be regarded as excess or surplus is displaced into the relief cavities 27 to form longitudinally extending ribs 28′ which may be so small as to be acceptable on the finished product.

It is important to note that at the final pressing stage of Figure 12 as well as in the intermediate pressing stage of Figure 9 the material which is displaced onto the rebates 16 and into the partially or wholly formed relief cavities 27 through the relief outlets 26′ and 26 is not subject to restraint on the rebates 16 (that is to say that the displaced material in Figure 12 has a volume less than and does not fill the relief cavities 27 and in Figure 9 does not fill the shouldered rebates 16). It is this maintenance of relief of lateral restraint on the workpiece material which is displaced through the relief outlets 26′ and 26 together with the restraint on the workpiece against longitudinal extension which is believed to relieve stress and shear forces developing in the body of the workpiece material as such material is displaced into the teeth 15 to the extent that the formation of fractured or otherwise malformed teeth is alleviated. Furthermore by providing the relief outlets 26 and also removing surplus material from the workpiece (as shown in Figure 10) following the initial pressing stage, it is found that the pressures required on the die parts for the final pressing (as shown in Figure 12) are considerably less than those pressures required in a conventional pressing technique to achieve closure of the die parts (as previously described with reference to diagrams B, C and D of Figure 1).

The previously mentioned clearances 18 adjacent to the rebates 16 ensure that during the final pressing stage (Figure 12) the material which is displaced through the relief outlets 26 to form the ribs 28′ is clear of the teeth 29′ which are pressed on the rack member 14*c* and thereby the profile and shape of the pressed teeth 29′ is an accurate moulding from the teeth 15.

It will be appreciated that the shouldered rebates 16 can alternatively (or in addition) be located in the upper die part 8 to open into its face 10; that the intial cross-sectional shape of the workpiece 14 is not necessarily circular, and that the workpiece is not necessarily of uniform or constant section over its longitudinal extent (indeed the workpiece may have rack teeth partially preformed therein, for example by machining, prior to the pressing operation although this is not preferred as previously discussed).

Claims

1. Apparatus for manufacturing a rack member comprising a press with openable and closable die parts for receiving a longitudinally extending workpiece on which longitudinally extending array of rack teeth is to be formed, said die parts when closed co-operating to provide a die cavity having a toothed wall part complementary in shape to the array of rack teeth which are to be pressed on the workpiece during closing of the die and wherein said die cavity has at least one laterally directed relief outlet communicating therewith in a parting plane of the die parts and clear of the toothed wall part through which excess material from said workpiece can be displayed laterally during the pressing of the teeth.

2. Apparatus as claimed in claim 1 in which stop means is provided for restraining the workpiece from longitudinal extension during pressing.

3. Apparatus as claimed in claim 2 in which the stop means comprises longitudinally opposed end stops for receiving the workpiece longitudinally therebetween, said end stops being formed as part of laterally displaceable support means for the workpiece which means is laterally displaceable with the workpiece during pressing.

4. Apparatus as claimed in any one of the preceding claims in which the or each relief outlet is so position with respect to the toothed wall part that excess material which is displaced therethrough does not detract from the required finished profile of the teeth when pressed as determined by the toothed wall part.

5. Apparatus as claimed in any one of the preceding claims in which the or a relief outlet extends longitudinally of the die parts to be substantially co-extensive with the rack teeth which are to be pressed.

6. Apparatus as claimed in claim 5 in which the or a relief outlet comprises a longitudinally extending slot formed between the die parts in a parting plane of those die parts so that excess material displaced through the or that relief outlet forms a longitudinally extending flange or rib on the workpiece following pressing.

7. Apparatus as claimed in any one of the preceding claims in which the relief outlet or outlets are located generally adjacent to but clear of the toothed wall part of the die parts.

8. Apparatus as claimed in any one of the preceding claims in which the or a relief outlet comprises a relief cavity which is formed between the die parts when closed and which communicates with the die cavity to receive excess material displaced therefrom from the workpiece during pressing.

9. Apparatus as claimed in any one of the preceding claims in which the or a relief outlet comprises a rebate in one or more of the die parts in the parting plane or planes with adjacent die part or parts.

10. Apparatus as claimed in any one of the preceding claims in which the die consists of two opposed die parts one of which has the toothed wall part complementary to the shape of rack teeth which are to be pressed and one of which die parts is rebated along its parting plane with the other to provide a relief outlet.

11. Apparatus as claimed in claim 10 in which two laterally opposed relief outlets are provided

by two longitudinally extending rebates in said die parts, said relief outlet extending longitudinally of the workpiece substantially parallel with and adjacent to the longitudinal extent of the complementary array of rack teeth provided in the toothed wall part of said one of the die parts.

12. Apparatus as claimed in claim 1 and substantially as herein described with reference to the accompanying illustrative drawings.

13. A method of manufacturing from a longitudinally extending workpiece a rack member having a longitudinally extending array of rack teeth which comprises locating the workpiece between opened die parts, said die parts being closable to co-operate and provide a die cavity having a toothed wall part complementary in shape to the array of rack teeth; closing the die parts under pressure to press the workpiece to a required shape of toothed profile and maintaining, during said closing and when closed, at least one laterally directed relief outlet which communicates with the die cavity in a parting plane of the die parts clear of the toothed wall part and through which excess material from the workpiece is displaced laterally during the pressing of the teeth.

14. A method as claimed in claim 13 which comprises restraining the workpiece from longitudinal extension during pressing of the teeth.

15. A method as claimed in either claim 13 or claim 14 which comprises displacing excess material from the workpiece through the or a relief outlet to provide a longitudinally extending flange or rib on the workpiece.

16. A method as claimed in any one of claims 13 to 15 which comprises pressing the teeth on a workpiece in which the teeth are partly preformed.

17. A method as claimed in any one of claims 13 to 15 which comprises the steps of partially forming the teeth on the workpiece during partial closing of the die parts; substantially removing from the workpiece the excess material displaced through the relief outlet or outlets, and subjecting the workpiece to further pressing to complete the tooth formation by full closure of the die parts.

18. A method as claimed in claim 17 which comprises removing the workpiece with its teeth partially formed from the die parts to effect removal of the excess material displaced through the relief outlet or outlets prior to further pressing of the workpiece.

19. A method as claimed in any one of claims 13 to 18 which comprises displacing excess materials from the die cavity through the or a relief outlet into at least one relief cavity formed between the die parts, the or each relief cavity having a volume greater than the voulme of excess material which it receives.

20. A method as claimed in claim 13 and substantially as herein described.

21. A rack member when manufactured by the method as claimed in any one of claims 13 to 20.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1983. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained